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[REDACTED]MEMORANDUM REPORT

for the

Army Air Forces, Air Technical Service Command

THE EFFECT OF SEVERAL ARMAMENT INSTALLATIONS ON THE DRAG

OF  $\frac{1}{8}$ -SCALE MODEL OF THE B-32 AIRPLANE

By R. W. Fairbanks, R. H. Neely, and D. W. Conner

Langley Memorial Aeronautical Laboratory  
Langley Field, Va.

December 30, 1944

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MEMORANDUM REPORT

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THE EFFECT OF SEVERAL ARMAMENT INSTALLATIONS ON THE DRAG

OF A  $\frac{1}{8}$ -SCALE MODEL OF THE B-32 AIRPLANE

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## SUMMARY

The effect of several armament installations on the drag of a  $\frac{1}{8}$ -scale model of the B-32 airplane was determined. Turrets in the following positions were tested: nose, tail, upper forward, upper aft, and lower. The nose and tail turrets were each equipped with two .50-caliber guns. Upper turrets were of three types: two .50-caliber guns, four .50-caliber guns, and 20-millimeter cannon. Lower turrets were of two types: two .50-caliber guns and four .50-caliber guns. The effect of streamlining the upper two- and four-gun turrets and of extending the lower two-gun turret was determined.

The tests were conducted in the Langley 19-foot pressure tunnel at a Reynolds number of approximately 2,960,000 and a Mach number of 0.13.

Large increases in drag coefficient were caused by the complete armament installations. At a lift coefficient of 0.4 the installations with nonstreamlined upper turrets and the lower turret retracted increased the drag coefficient by 0.0022 and 0.0027 for the two-gun and four-gun turret installations, respectively. Streamlining the upper turrets reduced the drag of these installations by approximately 40 percent. With the upper turrets streamlined, the drag increase was about the same for either the two- or four-gun turret installation. The streamlined two-cannon upper turrets increased the drag about the same amount as the two-gun upper turrets that were not streamlined. Extension of the lower turret increased the drag slightly more than the whole streamlined gun-turret installation.

## INTRODUCTION

At the request of the Army Air Forces, Air Technical Service Command, tests were conducted in the Langley 19-foot pressure tunnel to determine the effects of several armament arrangements on the drag of a  $\frac{1}{8}$ -scale model of the B-32 airplane.

Scale models of the following turrets were tested:

Upper turrets

Martin A3D (two .50-caliber guns) streamlined and not streamlined.

Sperry A-18 (four .50-caliber guns), streamlined and not streamlined.

Martin (two 20-millimeter cannon) streamlined.

Lower turrets

Sperry A-13A (two .50-caliber guns) retracted and extended.

Sperry A-19 (four .50-caliber guns) extended.

Nose and tail turrets

Sperry A-17 (two .50-caliber guns)

The effect of extending a radar dome was also determined.

These tests were conducted in July 1944 in conjunction with a series of clean-up tests of the B-32 model which are reported in reference 1.

## MODEL AND TESTS

The turrets were tested on a  $\frac{1}{8}$ -scale model of the production B-32 airplane. The general arrangement of the model is shown in figures 1 and 2.

The turrets tested were scale models of those being considered for use on the B-32 airplane. The various turrets are listed in table I together with the symbols used to designate them.

Figure 3 shows the general shape of the turrets and gives their over-all dimensions and location on the model. Figures 4 through 9 show the turrets mounted on the model. The turrets were made of wood and the guns of metal.

Upper turrets with two and four .50-caliber guns and two 20-millimeter cannon (figs. 4, 5, and 6) were attached directly to the surface of the fuselage. When these turrets were tested without the streamline fairing, they were placed in the normal cruising position for nonstreamlined turrets (guns pointed aft). When tested with the fairing, the guns pointed forward. The lower turret with two .50-caliber guns (fig. 7) was tested in both the retracted and extended position. The lower turret with four .50-caliber guns (fig. 8) was tested in the extended position only and the joint between the fuselage and the turret was faired with plasticene. In all cases the lower turret guns pointed aft.

The radar dome (fig. 10) was tested in both the partially and fully extended positions. In both cases, the dome was attached directly to the surface of the fuselage. For the partially extended condition, this installation corresponded to a partially extended dome with a seal around it. For all tests except the basic model test, mast and loop antennas were installed in conjunction with the armament. The mast antenna is shown in figures 5(b) and 6, and the loop antenna in figure 10(b).

The nose turret (fig. 9) and tail turret were built in as a part of the fuselage and were equipped with two .50-caliber guns. To represent the basic model with no armament, the guns were removed from the nose and tail turrets, and all other turrets, radar dome, and antennas were removed.

Drag, lift, and pitching moments were obtained for the basic model and for the model with several armament arrangements. In order to minimize the effect of variations of wing surface condition on drag, transition from laminar to turbulent flow was fixed by placing a strip of 60 grain (approx. 0.008 inch) carborundum on the upper and lower wing surfaces at the 10 percent chord station. The wing flaps were neutral; the landing gear, horizontal and vertical

tail surfaces, and propellers were removed. The tests were made at a Reynolds number of approximately 2,960,000 and a Mach number of about 0.13. The air in the tunnel was compressed to an absolute pressure of 35 pounds per square inch.

#### COEFFICIENTS AND SYMBOLS

$C_L$  gross lift coefficient ( $L/qS$ ) (gross denotes measured values)

$C_D$  drag coefficient ( $D/qS$ ) corrected for jet-boundary interference effects

$C_m$  gross pitching-moment coefficient ( $M/qSc$ )

$C_{D_i}$  induced drag coefficient  $(C_L^2/\pi A)$

$C_{D_p}$  parasite drag coefficient  $(C_D - C_{D_i})$

where

$L$  lift

$D$  drag

$M$  pitching moment about model support points, 0.525 foot behind the leading edge of the root chord and 0.183 foot above the root chord

$S$  wing area (22.2 sq ft)

$A$  geometric aspect ratio (12.8)

$c$  mean aerodynamic chord (1.444 ft)

$q$  dynamic pressure of the undisturbed airstream  $\left(\frac{1}{2}\rho V^2\right)$

$V$  velocity in the undisturbed air stream

$\rho$  mass density of air

and

$\alpha$  angle of attack of the wing corrected for jet-boundary interference effects

R      Reynolds number :  $(\rho V c / \mu)$

$\mu$     coefficient of viscosity of air

## RESULTS AND DISCUSSION

Drag data are presented in figures 11 to 13 as plots of parasite drag coefficient against lift coefficient. No support tares or air-stream misalignment corrections have been applied to the data but the drag coefficient and angle of attack have been corrected for jet-boundary interference effects. The increment of drag coefficient, at a lift coefficient of 0.4, which resulted from the various armament installations is presented in table II. These increments were obtained by taking the difference between the drag coefficient of the model with nose and tail turrets only, guns removed, and the drag coefficient with the armament listed and the mast and loop antennas. Also presented in table II are calculated changes in the high speed of the airplane which would result from the addition of the armament. The decrease in high speed,  $\Delta V$  was computed from the following expression:

$$\Delta V = V_{\text{initial}} \left( 1 - \sqrt[3]{\frac{C_D^{\text{initial}}}{C_D^{\text{with armament}}}} \right)$$

For an assumed high-speed lift coefficient of 0.4 at an altitude of 15,000 feet with a wing loading of 70.3 pounds per square foot, the initial velocity ( $V_{\text{initial}}$ ) is 331 miles per hour. The initial airplane drag coefficient ( $C_D^{\text{initial}}$ ) was assumed to be 0.0330.

In evaluating the drag increase (or speed decrease) due to a complete armament installation, it should be noted that the effect of the mast and loop antennas on the drag of the model is probably slight. Also, adding the guns to the nose and tail turrets caused a drag coefficient increase of only 0.0004 (drag coefficient with nose and tail guns obtained from reference 11). Therefore, the drag increment which is presented as that due to a complete armament installation is, in reality, approximately the increment due to the upper and lower turrets and also the radar dome, when it was extended.

It is possible that the drag increments may be somewhat in error due to interference effects between the lower turret and the tail strut. Similarly, the addition of the tail surfaces may change the drag increments.

In the following discussion a turret with two .50-caliber guns will be referred to as a two-gun turret, a turret with four .50-caliber guns as a four-gun turret, and a turret with two 20-millimeter cannon as a two-cannon turret.

The increases in drag coefficient at  $C_L = 0.4$  due to installations with nonstreamlined upper turrets and retracted lower turret were 0.0022 and 0.0027 for two-gun and four-gun turrets, respectively. Adding a streamline fairing to the upper turrets reduced the increment of drag coefficient due to the armament by 0.0009 in the case of the two-gun turrets and 0.0012 in the case of the four-gun turrets. With the upper turrets streamlined, the increment of drag coefficient was approximately 0.0014 for either installation. The computed increase in speed which would result from streamlining the upper turrets is 2.8 and 3.7 miles per hour for the two- and four-gun turret installations, respectively.

The drag-increase which resulted from the installation with streamlined two-cannon upper turrets was 0.0023 at a lift coefficient of 0.4. This is about the same as the increase with the nonstreamlined two-gun turrets. The high drag of the two-cannon turrets was probably due to the deep grooves in the upstream face (see fig. 6). The drag of these turrets would probably not have been much greater with the streamline fairing removed and the cannon pointed aft. The shape and size of this configuration would be similar to the two-gun turrets which caused a drag increase of 0.0022. The drag increase due to the aft upper two-cannon turret is shown in figure 11(c). In this case, the aft upper turret caused 39 percent of the drag increase due to the whole installation.

The increase in drag coefficient with the lower turret extended and the upper turrets streamlined was 0.0030 for the two-gun installation and 0.0034 for the four-gun installation (fig. 12). The increment of drag coefficient due to extending the lower turret was about 0.0018. This is slightly more than the increment due to the complete armament installation but with the lower turret retracted.

The computed decrease in airplane velocity which would result from extending the lower two- or four-gun turret is 5.2 and 5.7 miles per hour, respectively.

Extending the radar dome partially and fully caused drag coefficient increments of 0.0006 and 0.0015, respectively, at a lift coefficient of 0.4 (fig. 13).

None of the armament installations changed the lift or pitching moment. Lift and pitching-moment curves for the basic model and the model with a representative armament installation are presented in figure 14.

#### SUMMARY OF RESULTS

The results of an investigation to determine the effects of armament on the aerodynamic characteristics of a  $\frac{1}{8}$ -scale B-32 model are briefly summarized below:

1. The drag coefficient increments due to the two- and four-gun installations, upper turrets not streamlined and lower turrets retracted, were 0.0022 and 0.0027, respectively, at a lift coefficient of 0.4.

2. Streamlining the upper turrets reduced the drag-coefficient increments by 0.0009 and 0.0012 for the two- and four-gun installations, respectively, at a lift coefficient of 0.4.

3. Extending the lower turret (either two- or four-gun) increased the drag coefficient about 0.0018.

4. The streamlined two-cannon upper turrets increased the drag about the same amount as the nonstreamlined two-gun turrets.

5. The installation of armament did not change either the lift or pitching moment of the model.

Langley Memorial Aeronautical Laboratory  
National Advisory Committee for Aeronautics  
Langley Field, Va., December 30, 1944

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REFERENCE

1. Neely, R. H., Fairbanks, R. W., and Conner, D. W.:  
Clean-Up Tests of a  $\frac{1}{8}$ -Scale Model of the B-32  
Airplane in the Langley 19-Foot Pressure Tunnel.  
NACA MR No. L4L30, Army Air Forces, 1944.

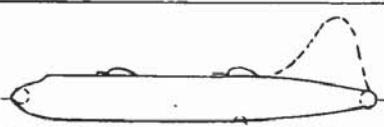
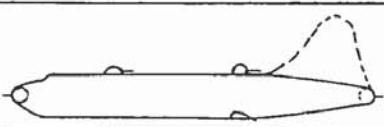
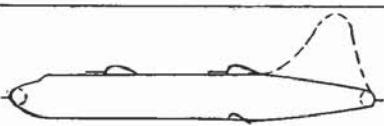
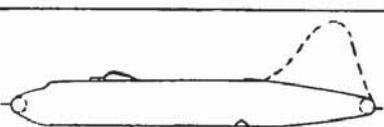
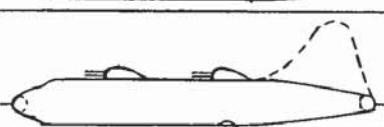
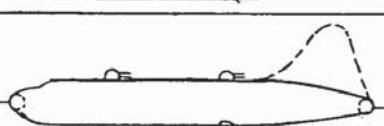
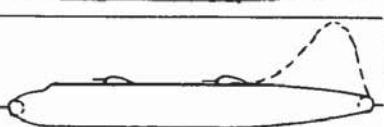
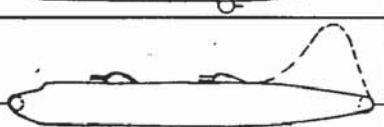
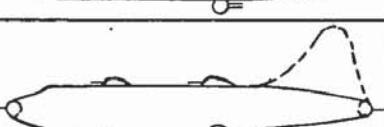
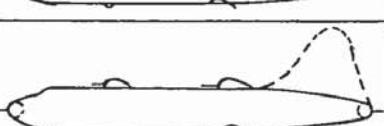
TABLE I  
DESIGNATION OF TURRETS

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Designation	Item
A	Nose turret, Sperry A-17, two .50-caliber guns.
B	Tail turret, Sperry A-17, two .50-caliber guns.
C <sub>1</sub>	Upper forward turret, Martin A3D streamlined, two .50-caliber guns.
C <sub>2</sub>	Upper, aft turret, Martin A3D streamlined, two .50-caliber guns.
D <sub>1</sub>	Upper forward turret, Martin A3D not streamlined, two .50-caliber guns.
D <sub>2</sub>	Upper aft turret, Martin A3D not streamlined, two .50-caliber guns.
E <sub>1</sub>	Upper forward turret, Martin streamlined, two 20-millimeter cannon.
E <sub>2</sub>	Upper aft turret, Martin streamlined, two 20-millimeter cannon.
G <sub>1</sub>	Upper forward turret, Sperry A-18 streamlined, four .50-caliber guns.
G <sub>2</sub>	Upper aft turret, Sperry A-18 streamlined, four .50-caliber guns.
H <sub>1</sub>	Upper forward turret, Sperry A-18 not streamlined, four .50-caliber guns.
H <sub>2</sub>	Upper aft turret, Sperry A-18 not streamlined, four .50-caliber guns.
I	Lower turret, Sperry A-13A retracted, two .50-caliber guns.
J	Lower turret, Sperry A-13A extended, two .50-caliber guns.
K	Lower turret, Sperry A-19 extended, four .50-caliber guns.
L	Radar dome - partially extended.
M	Radar dome - fully extended.

TABLE II  
INCREMENT OF DRAG COEFFICIENT DUE TO VARIOUS ARMAMENT INSTALLATIONS

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Configuration	Nose and tail turrets	Upper forward and aft turrets	Lower turret	Radar dome	Increment of drag coefficient due to armament, $C_L = 0.4$ (1)	Computed decrease in airplane high speed due to armament, (mph) (2)
	Sperry A-17 two .50-caliber guns (A and B)	Martin A3D streamlined two .50-caliber guns (C <sub>1</sub> and C <sub>2</sub> )	Sperry A-13A retracted two .50-caliber guns (I)	off	0.0013	4.2
	---do---	Martin A3D not streamlined two .50-caliber guns (D <sub>1</sub> and D <sub>2</sub> )	---do----	off	.0022	7.0
	---do---	Martin streamlined two 20mm cannon (E <sub>1</sub> and E <sub>2</sub> )	---do----	off	.0023	7.3
	---do---	Martin streamlined two 20mm cannon forward only (E <sub>1</sub> )	---do----	off	.0014	4.6
	---do---	Sperry A-18 streamlined four .50-caliber guns (G <sub>1</sub> and G <sub>2</sub> )	---do----	off	.0015	4.9
	---do---	Sperry A-18 not streamlined four .50-caliber guns (H <sub>1</sub> and H <sub>2</sub> )	---do----	off	.0027	8.6
	---do---	Martin A3D streamlined two .50-caliber guns (C <sub>1</sub> and C <sub>2</sub> )	Sperry A-13A extended two .50-caliber guns (J)	off	.0030	9.5
	---do---	Sperry A-18 streamlined four .50-caliber guns (G <sub>1</sub> and G <sub>2</sub> )	Sperry A-19 extended four .50-caliber guns (K)	off	.0034	10.6
	---do---	Martin A3D streamlined two .50-caliber guns (C <sub>1</sub> and C <sub>2</sub> )	Sperry A-13A retracted two .50-caliber guns (I)	partially extended (L)	.0019	6.1
	---do---	---do----	---do----	fully extended (M)	.0028	8.9

<sup>1</sup>Difference between the drag of the model with nose and tail turrets only, with guns removed, and the drag with the armament listed and the mast and loop antennae.

<sup>2</sup>Based on an assumed initial velocity of 331 mph, and an assumed airplane drag coefficient of 0.0330.

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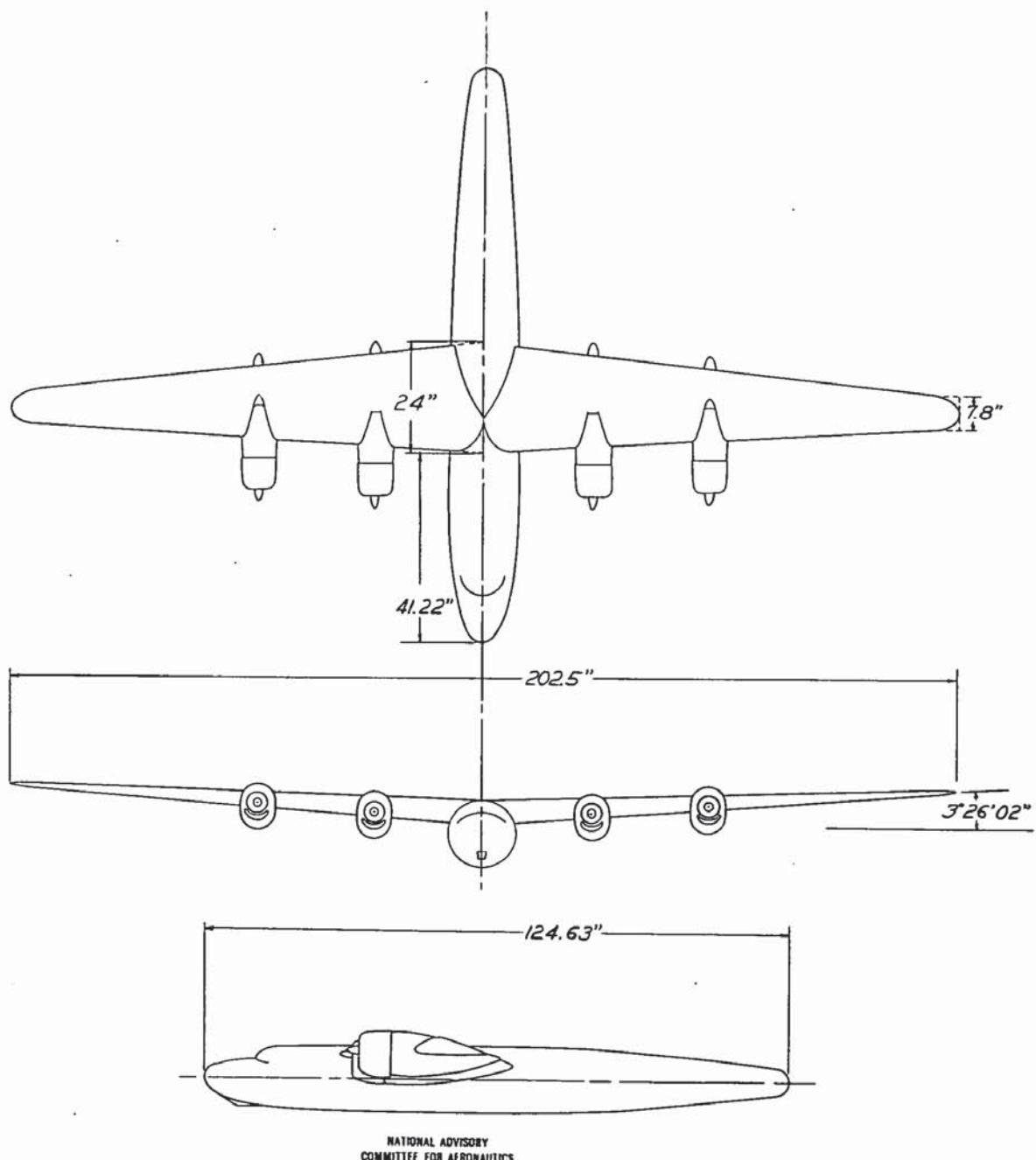


Figure 1. - 1/8-Scale Wind Tunnel Model of the  
Consolidated-Vultee B-32 Airplane

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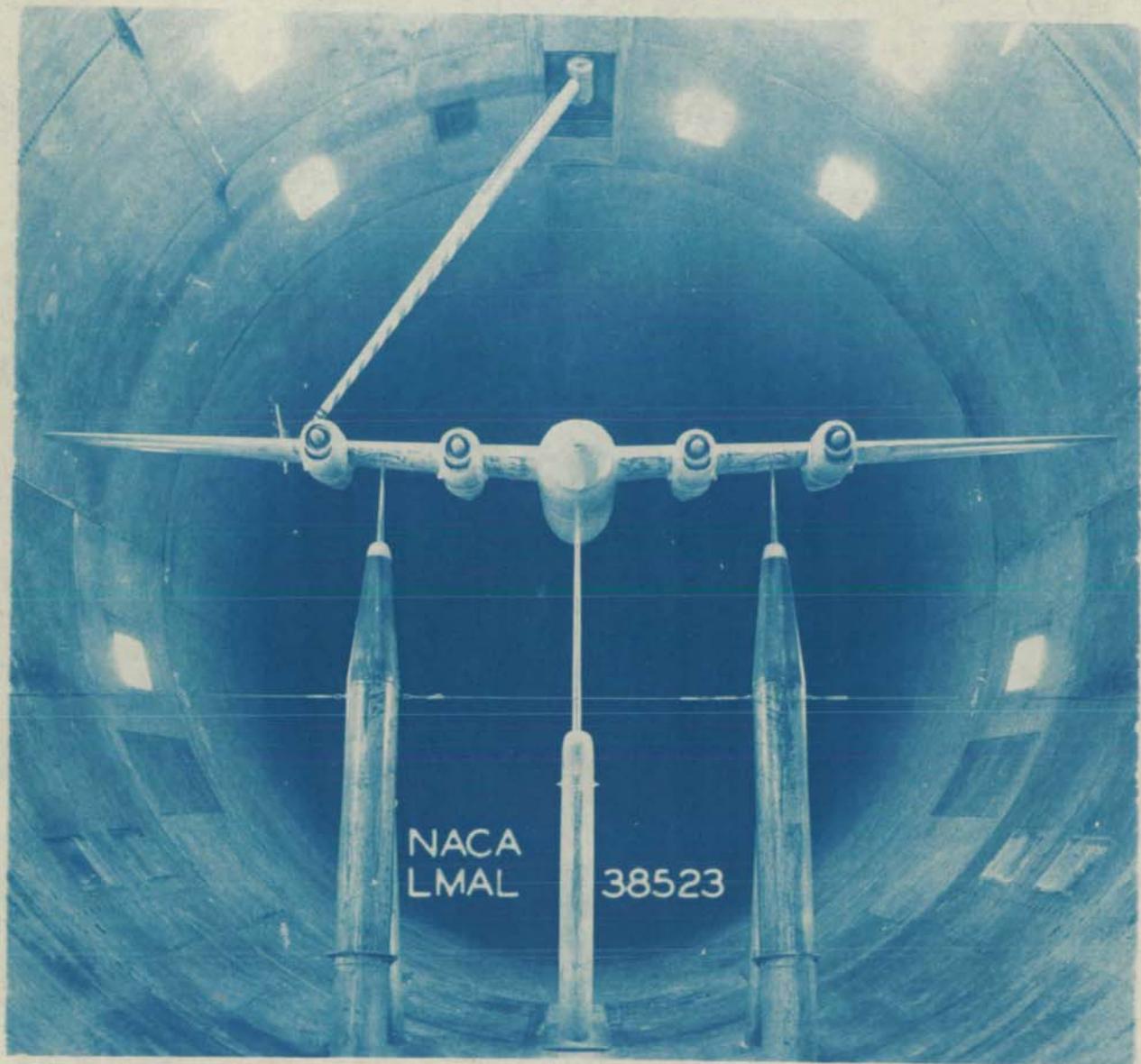


Figure 2.-  $\frac{1}{8}$ -scale B-32 model in the test section.

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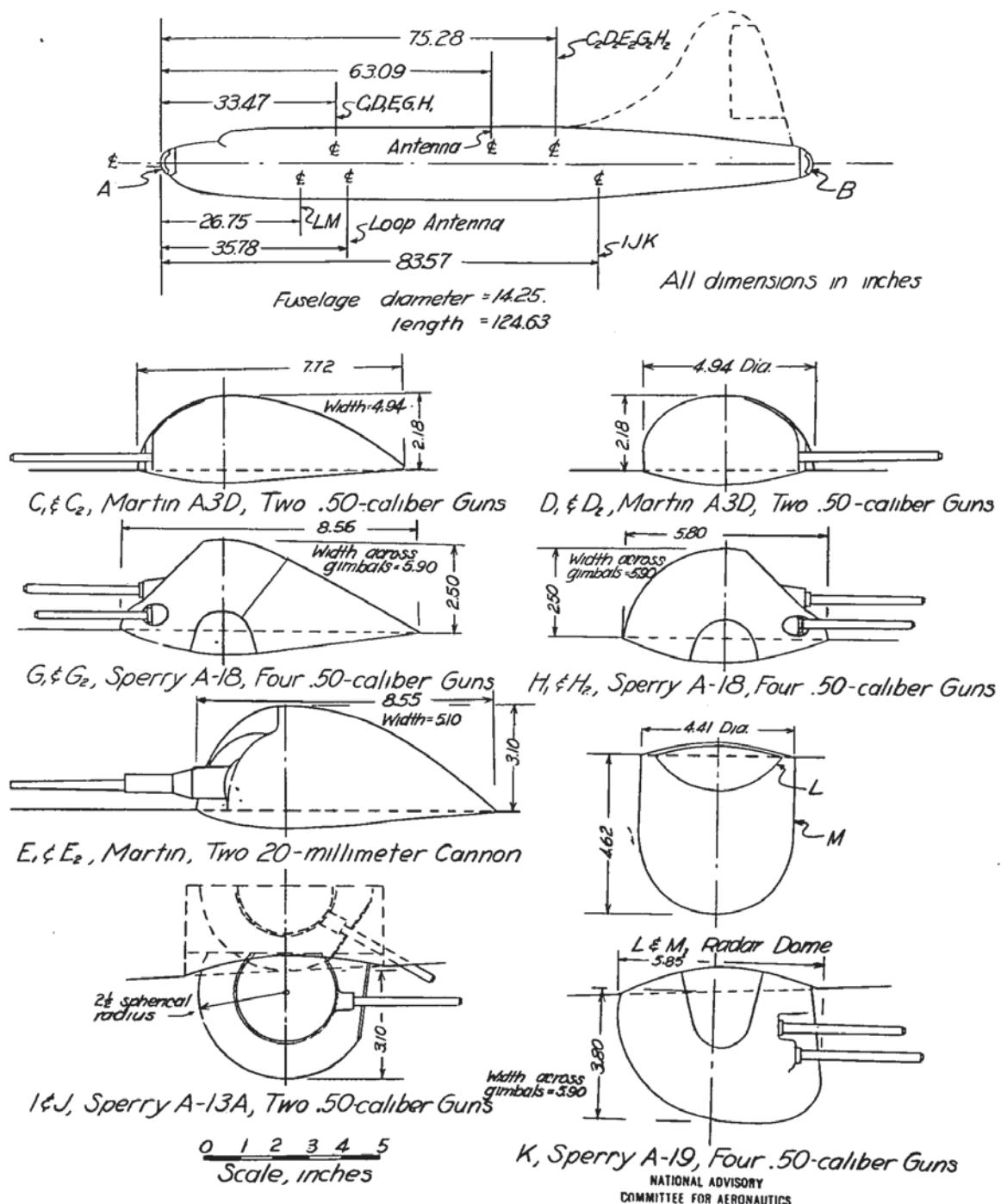


Figure 3 - Location and general shape of turrets on a 1/8-scale model of the B-32 airplane.

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(a) Streamlined, C.



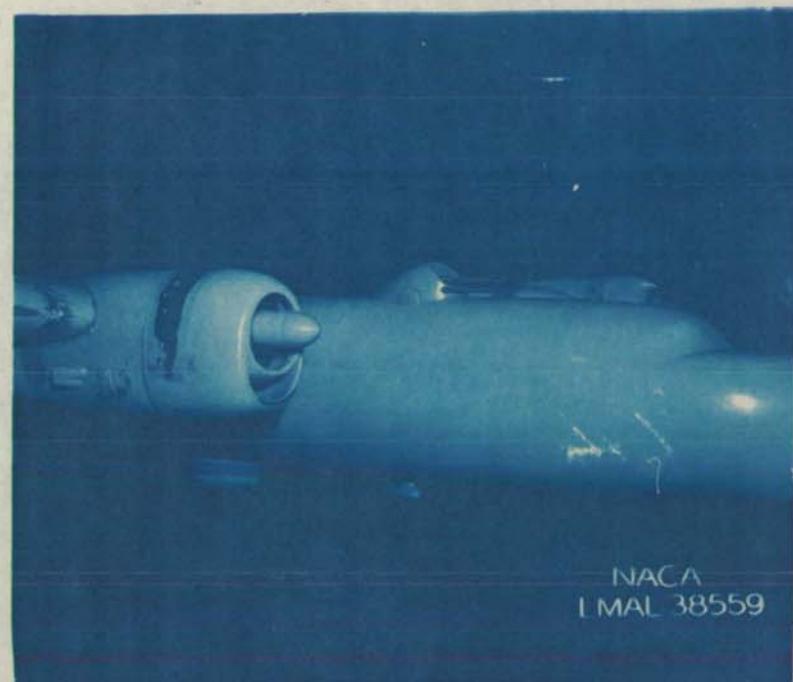
(b) Not streamlined, D.

Figure 4.- Upper turrets, Martin A-3D, two .50-caliber guns.

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UD  
P.  
G.  
H.

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(a) Streamlined, G.



(b) Not streamlined, H.

Figure 5.- Upper turrets, Sperry A-18, four .50-caliber guns.

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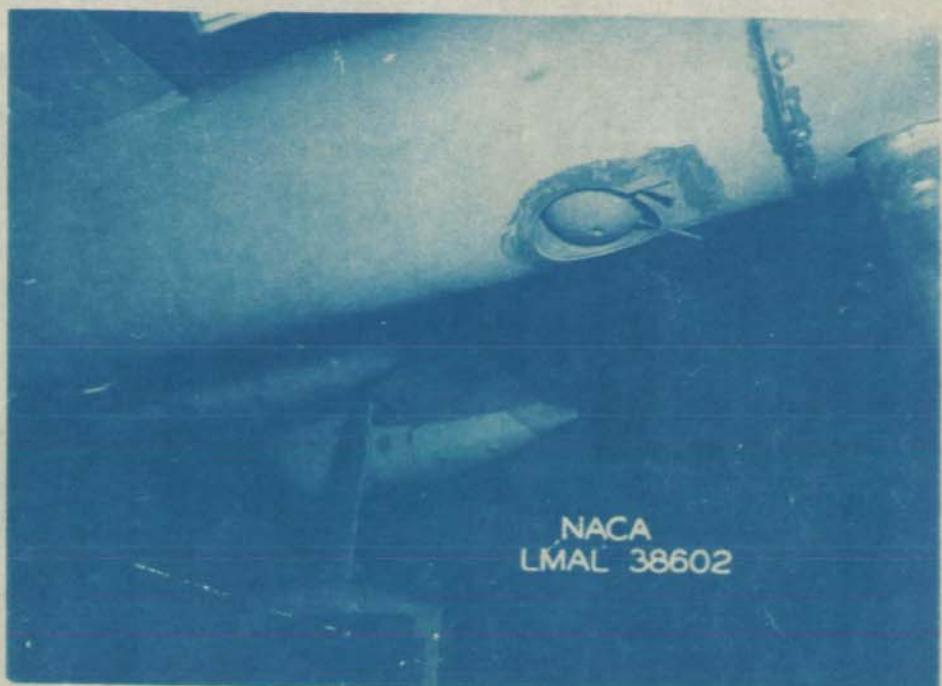
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Figure 6.- Upper turret (E), Martin stream-lined, two 20-millimeter cannon.

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(a) Retracted, I.



(b) Extended, J.

Figure 7.- Lower turret, Sperry A-13A, two .50-caliber guns.

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Figure 8.- Lower turret (K), Sperry A-19  
extended, four .50-caliber guns.

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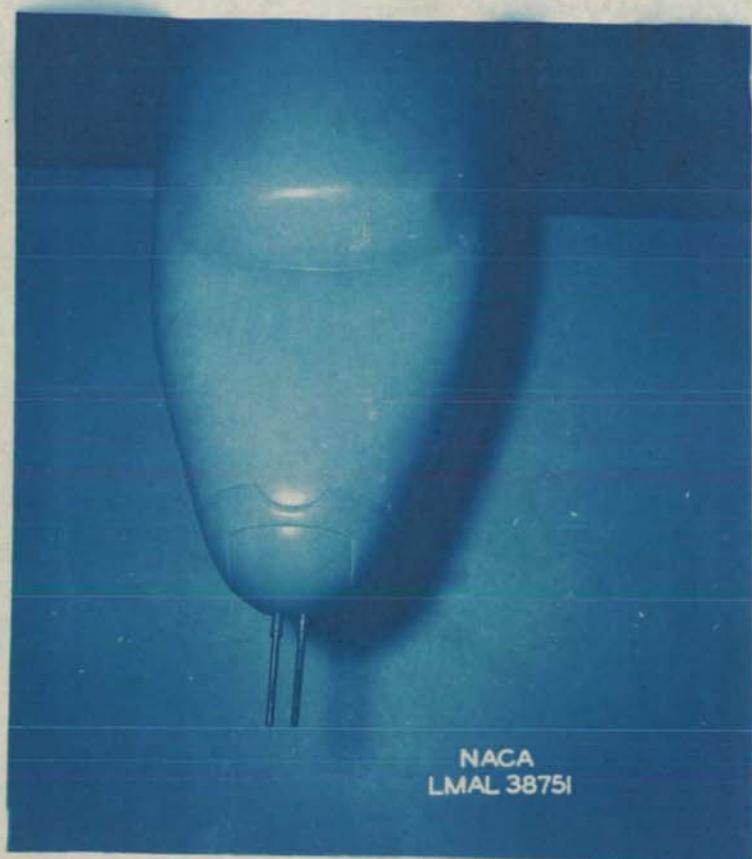


Figure 9.- Nose turret (A), Sperry A-17,  
two .50-caliber guns.

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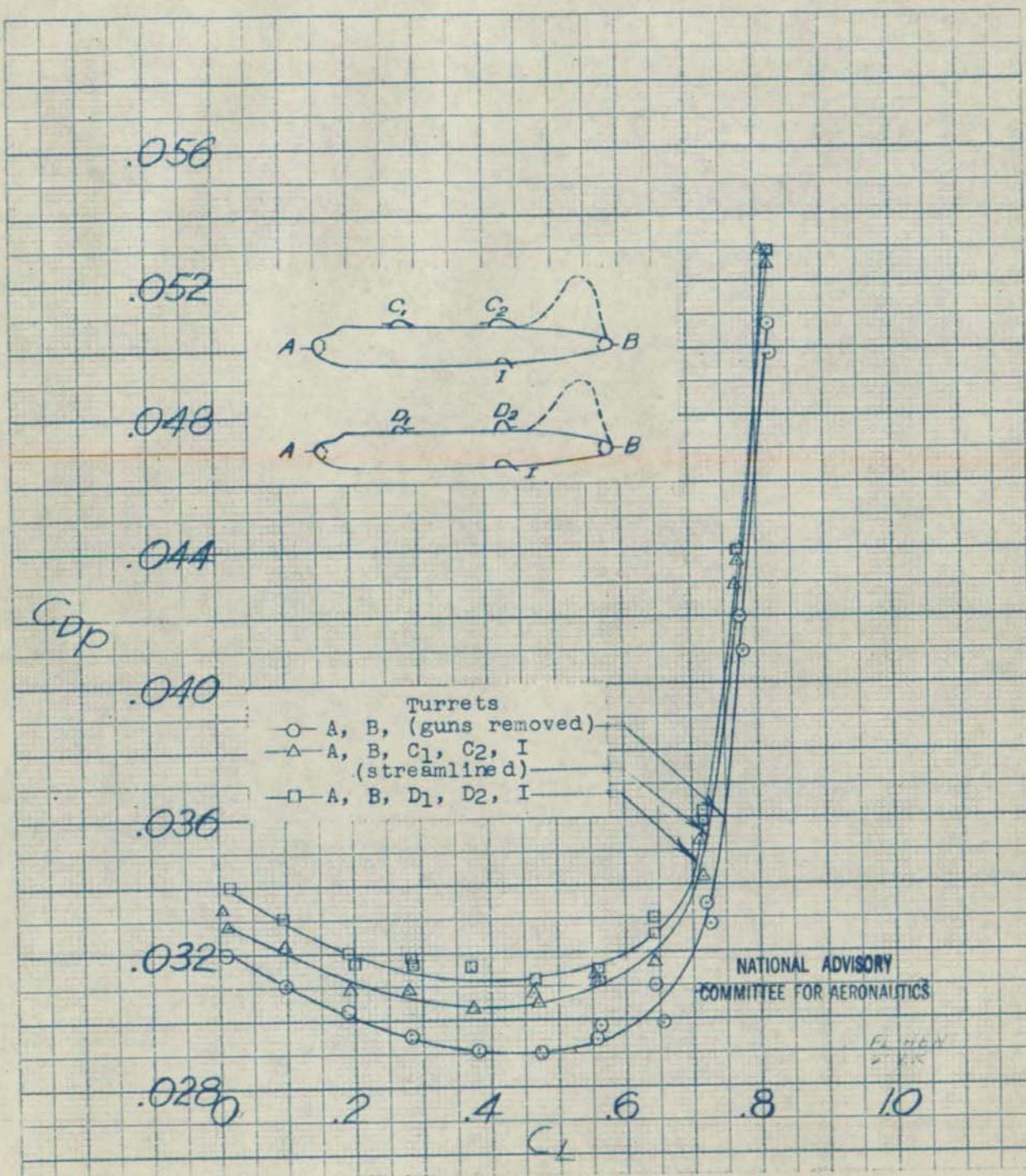
(a) Partially extended, L.



(b) Fully extended, M.

Figure 10.- Radar dome.

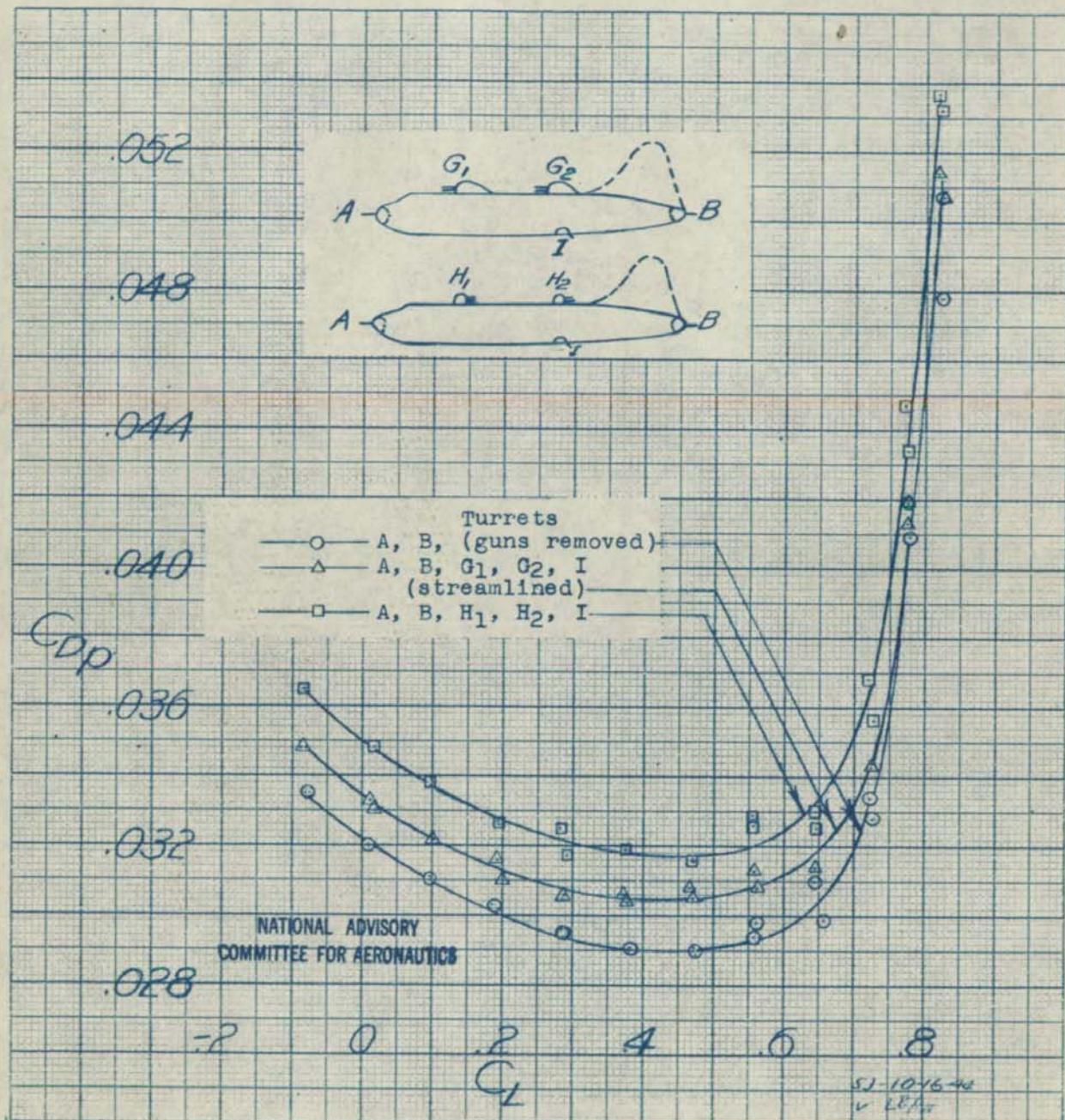
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(a) Turrets with two .50-caliber guns.

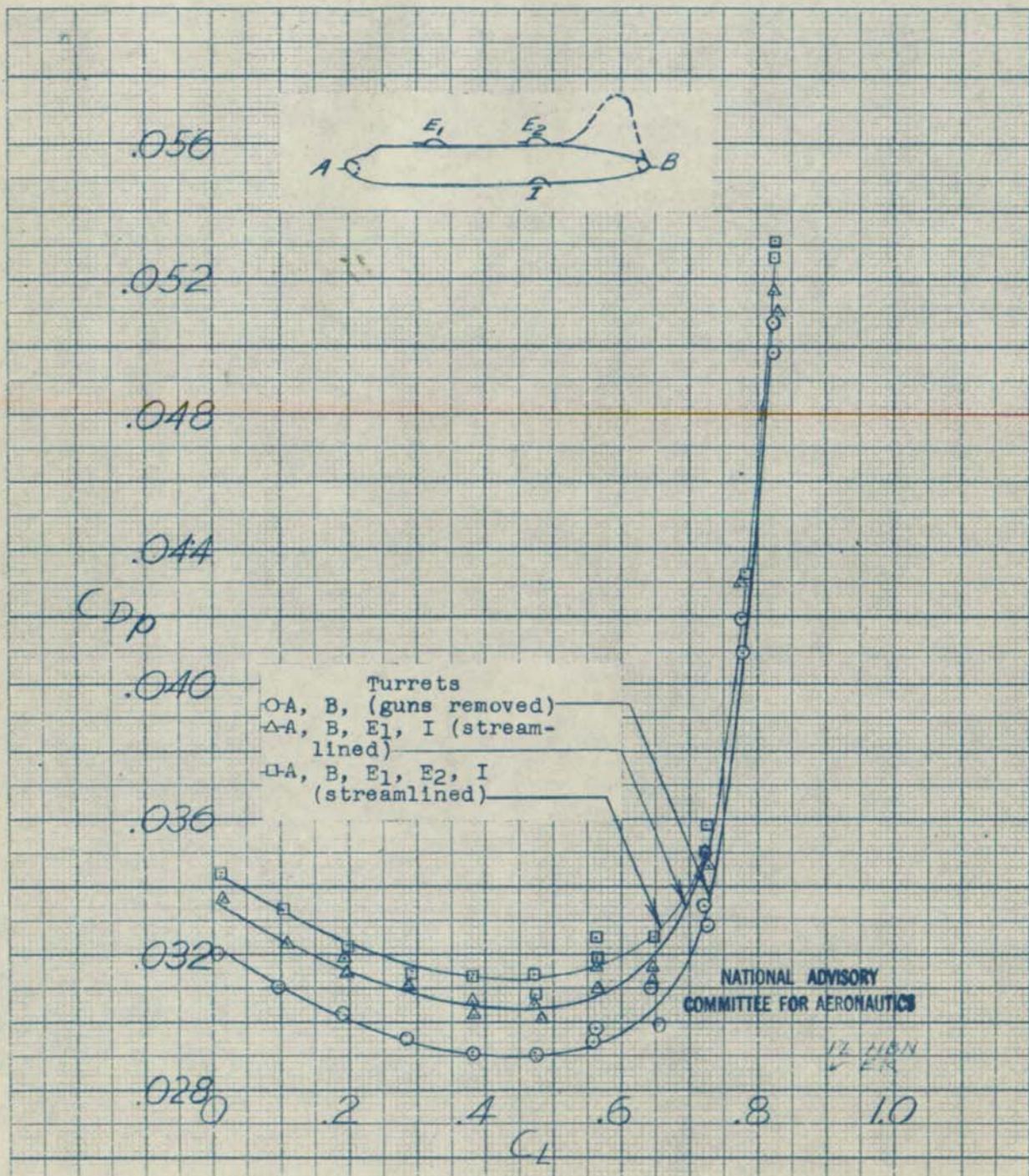
Figure 11.- Drag characteristics with upper turrets streamlined and not streamlined, lower turret retracted.  $R \approx 2,960,000$ .

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(b) Turrets with four .50-caliber guns.

Figure 11.- Continued.



(c) Turrets with two 20-millimeter cannon.

Figure 11.-- Concluded.

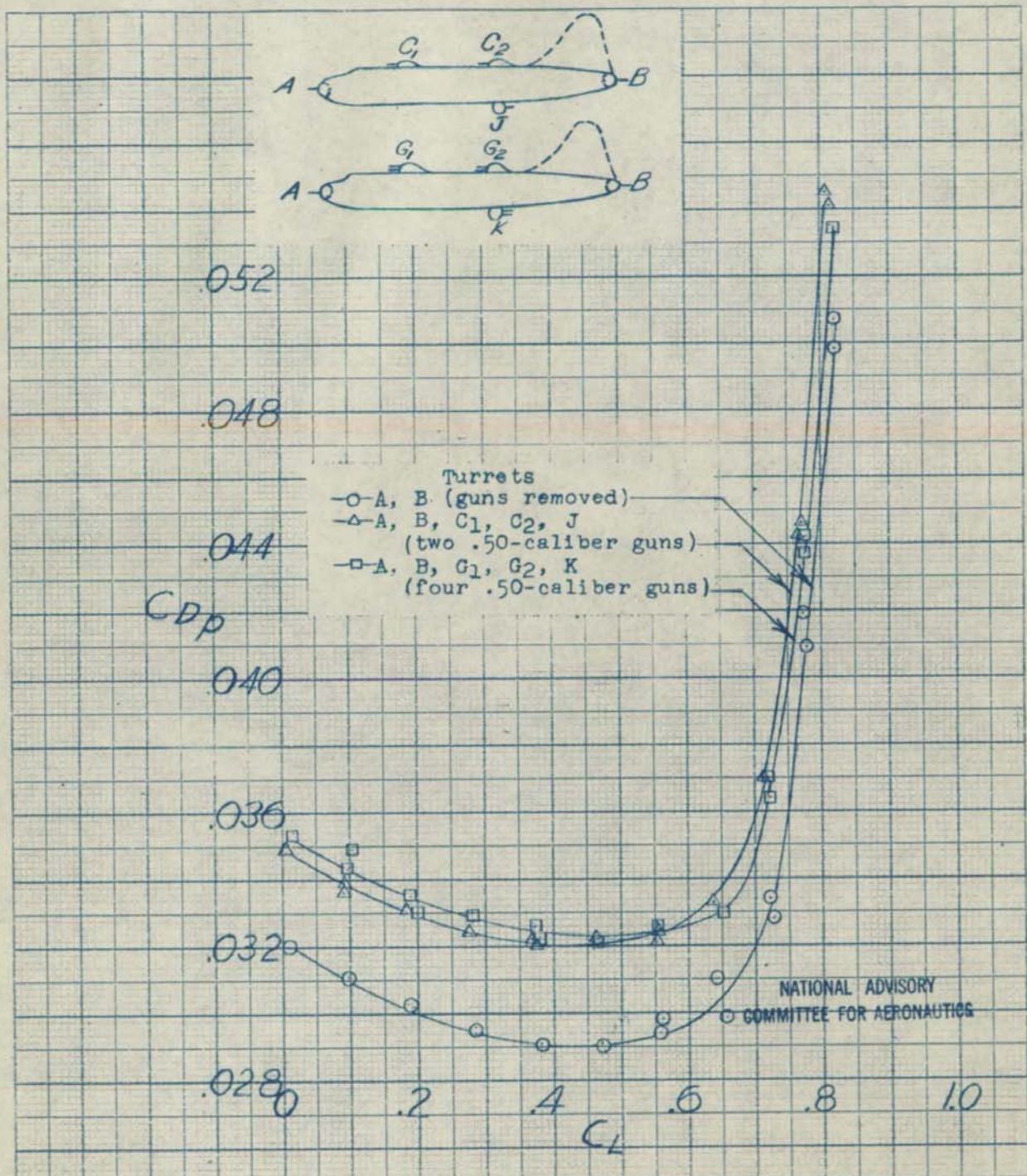


Figure 12. - Drag characteristics with lower turret extended, upper turrets streamlined.  $R \approx 2,960,000$ .

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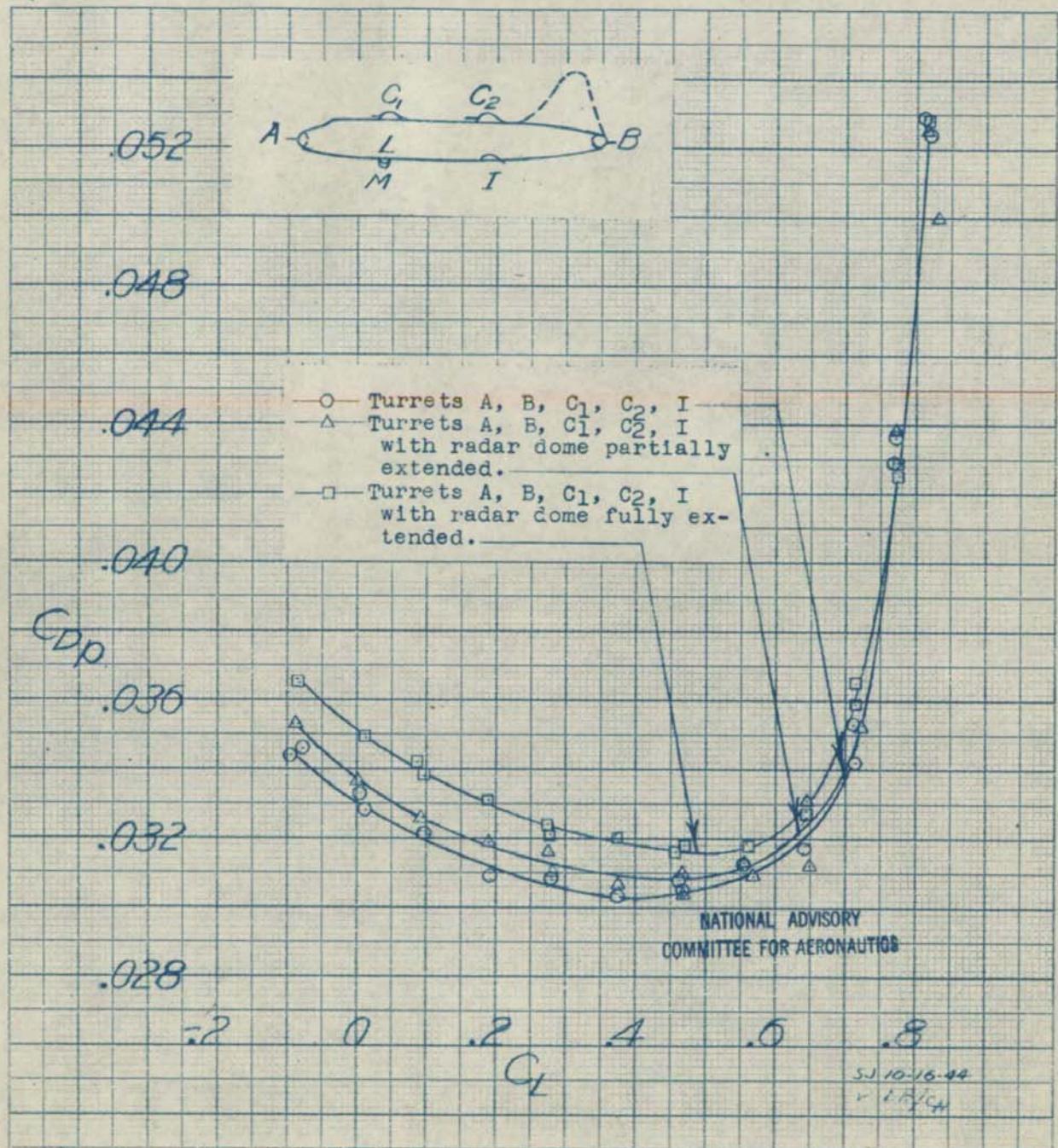


Figure 13 .- Drag characteristics with radar dome extended.  
 $R \approx 2,960,000$ .

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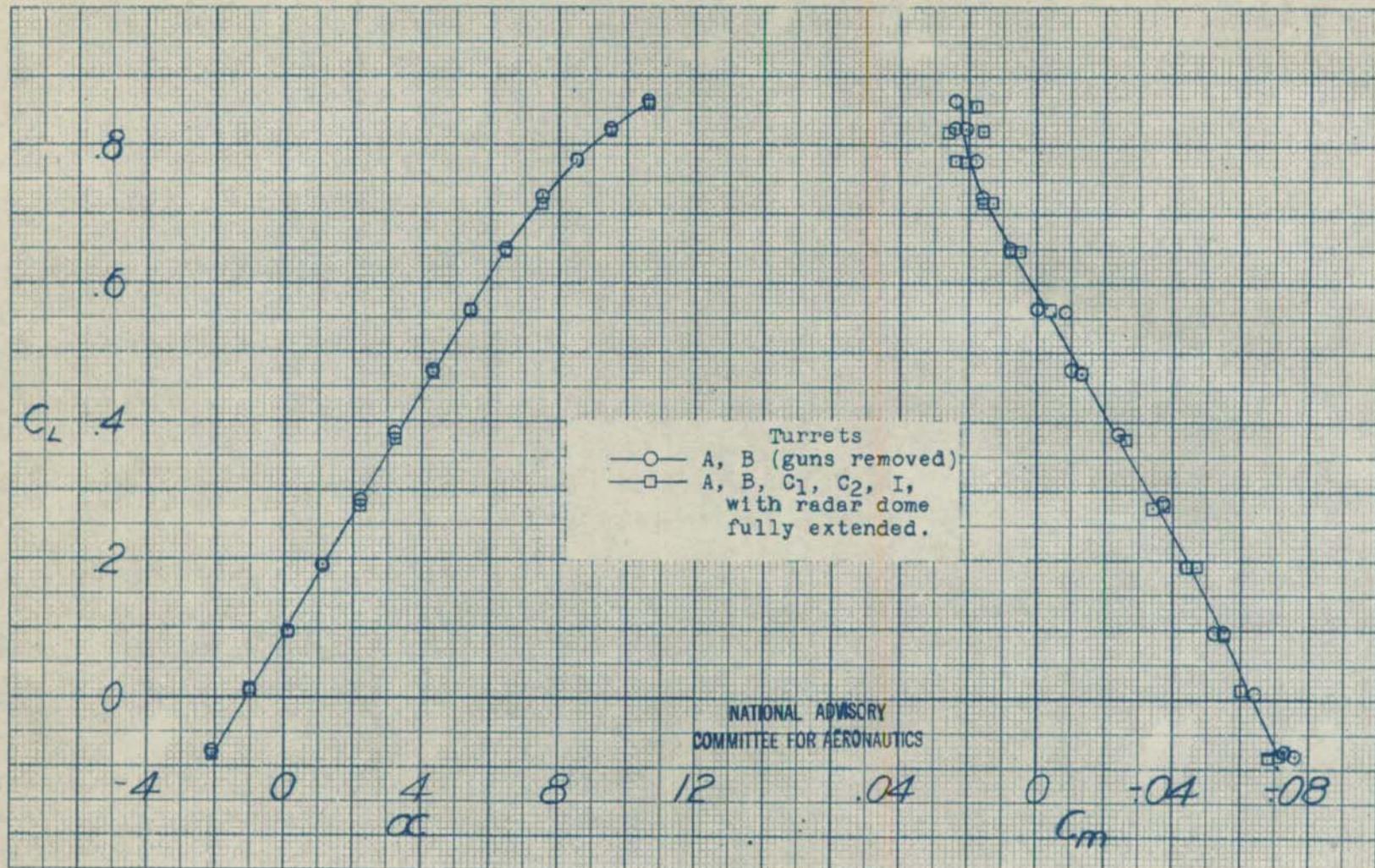


Figure 14 .- Lift and pitching-moment characteristics, with and without armament.  
 $R \approx 2,960,000$ .

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AUTH: A/FAIRBANKS, R.W.; B/NEELY, R.H.; C/CONNELL, D.W.

CORP: NACA

SLN: 1105.5 Consolidated Vultee B-32/1

MISC: PROPRIETARY -- NACA MR L4L30a RMR for AAF ATSC. Classification cancelled  
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SUBJ: /Airplanes - Consolidated Vultee B-32. / Wind tunnel tests  
(NACA-Pressure-19')(Amer.). /Drag reduction - Consolidated Vultee B-32.  
/Gun turrets - Martin. /Gun turrets - Sperry. /Wind tunnel tests - NACA -  
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Restriction/Classification Cancelled

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